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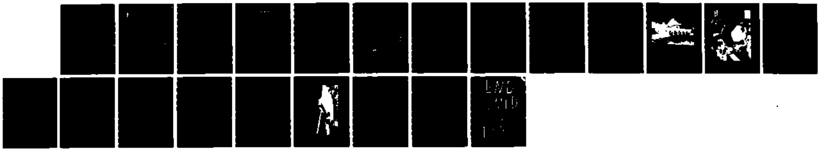

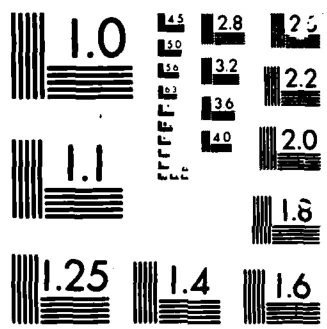

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Technical Note 1-86

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Ronald W. Cammarata

January 1986

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U. S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

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The Fire Control Research System (FCRS) was developed by Delco Systems Operations for the Human Engineering Laboratory as a one-of-a-kind test bed for conducting human factors research in the area of tank fire control. System tests were performed on the FCRS to 1) identify and correct outstanding operational deficiencies; 2) ensure that the system is capable of functioning in an in-the-field test environment; and 3) obtain a preliminary measure of firing accuracy. The tests indicated that, although the

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system performed sufficiently in some human factors research, further testing to determine inherent FCRS armament delivery accuracy is necessary.

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EXECUTIVE SUMMARY

In September 1984, over a period of 2 weeks, the Human Engineering Laboratory's Fire Control Research System (FCRS) was put through a number of system evaluation tests to determine if the system was fully operational. The tests examined the following aspects of system performance:

- How well the FCRS could be aligned (bringing the system's sight and gun into coincidence) and zeroed (ensuring that rounds fired impacted the target where the sight was pointed).
- Round-to-round dispersion of the FCRS armament delivery system (M2 machine gun firing .50 caliber ball ammunition).
- Ability of the system to hit a manned moving vehicle, traveling left to right and right to left, perpendicularly in front of the FCRS.
- Operability of the system's tracking aids function.

Results from these tests indicated that:

- The system could be properly aligned and zeroed.
- As a measure of system accuracy, the mean distance from the target aim point in azimuth and elevation, for 51 rounds fired after the weapon was zeroed (12 ft x 12 ft stationary target at a range of 500 meters), was found to be +0.07 mil with a standard deviation of 0.34 mil, and -0.4 mil with a standard deviation of 0.74 mil, respectively. For dispersion, the overall standard deviations of the means of the shot pattern on the target in the x and y directions were 0.29 mil and 0.40 mil, respectively.
- The system can engage and hit at 500 meters a vehicle which is moving left to right or right to left. For all moving-target conditions, 100-percent hits were achieved.
- The system's tracking aids function is operable and can be controlled by computer software.

The conclusions drawn from the results are that:

- The FCRS is currently operational, but it should be upgraded further to be more capable of simulating a wider variety of modern tank fire control systems.

- Because it is essential to know which changes in soldier-machine performance are attributable to the human operator and which are attributable to the machine, the FCRS should undergo further testing to more fully determine armament delivery accuracy. This will begin providing the Army with a data base on fire control system performance, emphasizing the "man in the loop."

INITIAL ENGINEERING TESTS OF THE HUMAN ENGINEERING LABORATORY'S FIRE CONTROL RESEARCH SYSTEM (FCRS)

INTRODUCTION

In 1981, in response to a need identified by the Human Engineering Laboratory (HEL) for a human factors research tool in the area of tank fire control, Delco Electronics Division, now Delco Systems Operations (DSO), General Motors Corporation, began work on developing a tank-mounted fire control research system under contract DAAK-81-C-0092. The final result of this effort is the Fire Control Research System (FCRS) which was delivered to the HEL in June 1983 (see Figure 1). A modified M551 Sheridan Vehicle, the FCRS extensively uses government-furnished equipment (GFE), mostly surplus components from the MBT-70 and XM-803 programs and commercially available computer equipment. Equipped with an M2 machine gun, in place of the main tank gun, the system fires relatively inexpensive .50 caliber ball ammunition instead of expensive large caliber main tank gun rounds. This also reduces the range area necessary for live-fire testing.

The FCRS will be used to develop a soldier-machine system performance data base which will permit identification of fire control system parameters which have the greatest payoff in regarding battlefield effectiveness. The FCRS has the potential to be a very effective tool for determining how best to use the capabilities of the human operator of tank fire control systems. In addition, the FCRS is uniquely capable of allowing assessments of the increases in battlefield performance of fire control systems relative to increases in system complexities and costs, and of new fire control concepts before any hardware is built.

The FCRS is a flexible system with the potential for increased capabilities as fire control technology progresses. The system configuration currently includes the following features:

Interchangeable gunner's controls. In addition to conventional isotonic gunner's controls, the system has an interchangeable set of specially-developed thumb-tracker isometric controls (see Figure 2). Both sets of controls allow the gunner to set range inputs for fire control calculations as well as select sight magnification.

Tracking aids. The system's lead computation algorithms in both azimuth and elevation can be changed via computer software.

Programmable burst fire. The rate and number of rounds fired per burst of the FCRS M2 machine gun can be programmed to simulate the rate of fire of any current or projected tank main gun system, including single shot.

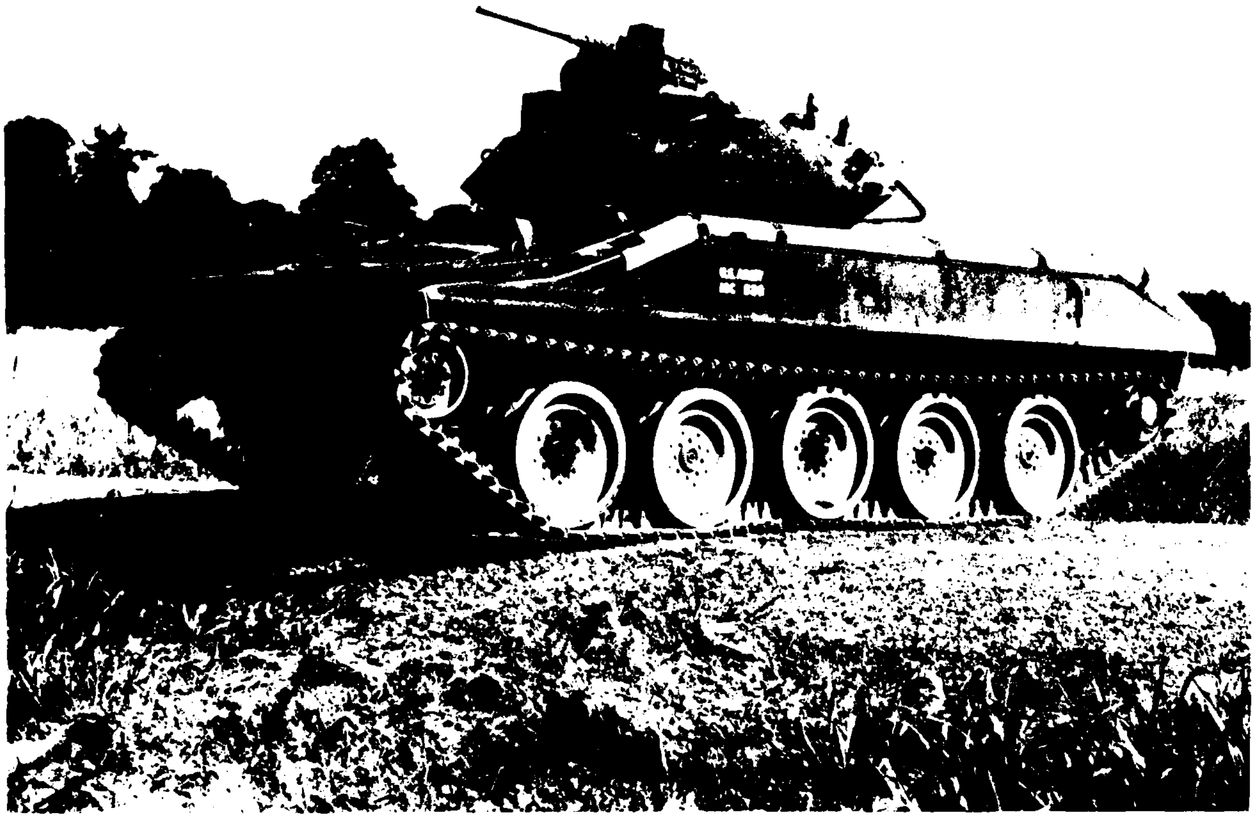

Figure 1. HEL's Fire Control Research System (FCRS).

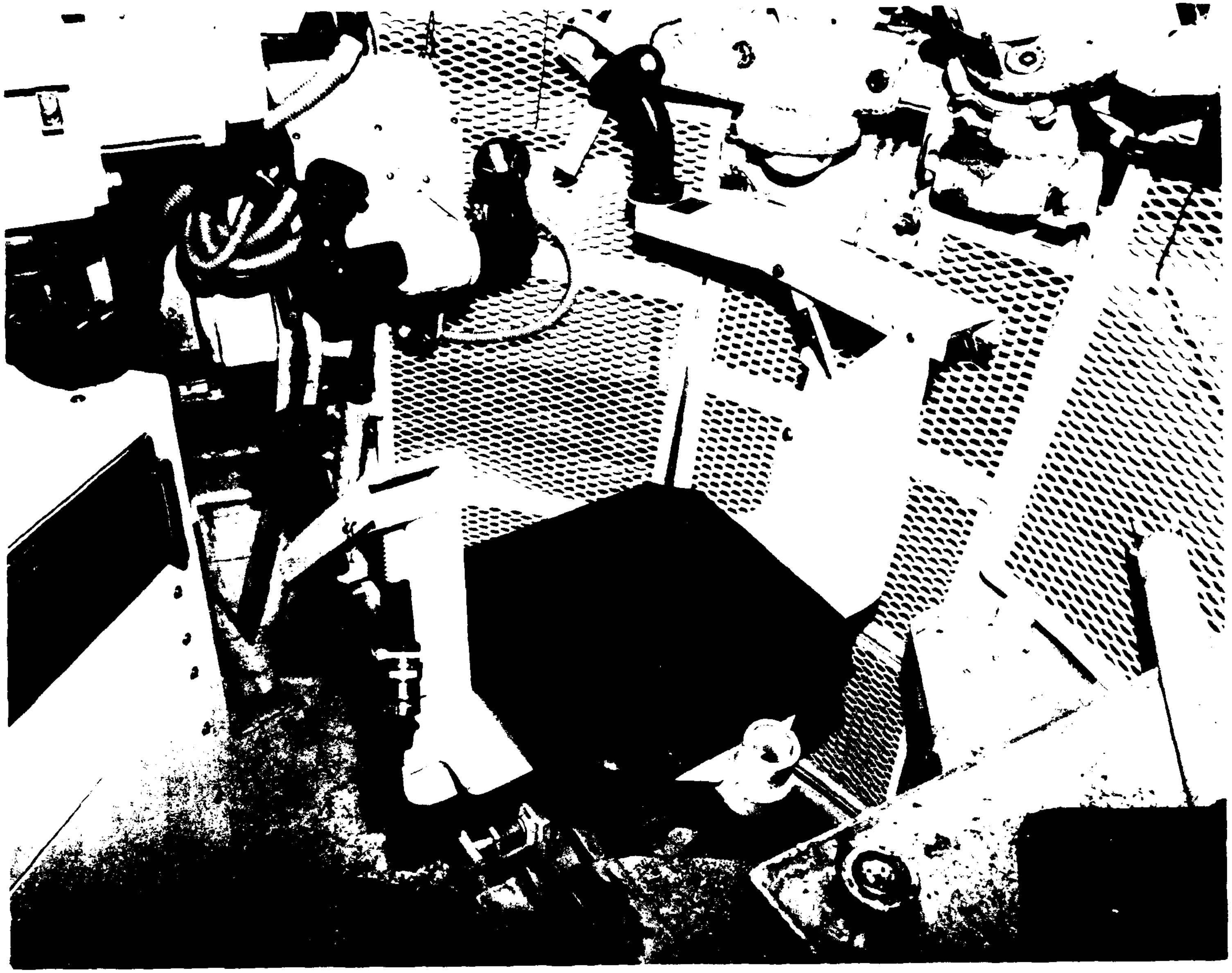

Figure 2. Interchangeable FCRS gunner's controls.

Dispersion selection. The system's round-to-round dispersion can be increased through programming. This can permit an evaluation of increasing the first round hit probability by purposefully increasing system dispersion.

Variable sight magnification. The gunner's telescope, a surplus item from the MBT-70 program, is equipped with a zoom, and the magnification can be increased and decreased from the gunner's control handles. Any one of four magnifications can be selected: 7X, 8X, 11X, and 14X.

Data collection and retrieval system. The FCRS is equipped with a militarized Norden PDP 11/34 computer and Wespercorp ruggedized tape drives. Fire control data (times to fire, tracking rates, etc.) can be collected directly by the FCRS and can be retrieved via a computer support station.

In addition to these features, the system has the capability to accommodate the additions of an integrated commander's station, a through-sight neodymium laser range finder, and an automatic rate-aided tracking system to facilitate the tracking of intermittently-sighted moving targets. The FCRS can also accommodate almost any new fire control technology improvement.

When system evaluation tests were begun in November 1983, problems with software, and the lack of an operating computer support station to modify the software, prevented the system from being operated as anticipated. After examining the support station tape drives and repairing the damaged ribbon cables as well as modifying the software, a new series of engineering tests was begun to troubleshoot the system and eliminate any remaining bugs.

Over a period of about 5 months, beginning in April 1984, the HEL and Delco Systems Operations tested the FCRS under field conditions. During this testing, there were a number of component failures which prevented continued successful operation of the system. After the replacement or repair of these, a number of engineering tests were performed on the system.

OBJECTIVES

The objectives of the tests were: 1) to identify and correct any outstanding operational deficiencies in the FCRS. 2) to verify alignment and zeroing procedures. 3) to ensure the system's ability to function in the field, without serious failures, under stationary firer/stationary target, and stationary firer/moving-target conditions, and 4) to obtain a preliminary measure of system firing accuracy.

METHOD

Participants

All tests were conducted exclusively by personnel from the Human Engineering Laboratory and Delco Systems Operations.

Turret operations, including weapon firing (except during gunner laying tests), were performed by a DSO technician familiar with the design and fabrication of the system.

Sight laying operations during the gunner laying tests were performed by each of two HEL personnel--one military and one civilian. Neither participant was familiar with the operation of the FCRS nor had had any prior training.

Weapon mounting and loading was performed by HEL personnel qualified to handle and fire the .50 caliber machine gun.

All automotive operations were handled by HEL personnel qualified to drive an M551 Sheridan Assault Reconnaissance Vehicle.

Procedures

Alignment, Zeroing, and Round-to-Round Dispersion. The first system test we performed, with the FCRS firing from a stationary position against a stationary target, evaluated the boresighting and zeroing procedures. The weapon was aligned and zeroed in accordance with the operations manual, FCRS Vehicle Customer Orientation and Training (Section II - Operation and Maintenance). The FCRS is aligned by pointing both the machine gun and gunner's sight at a common aiming point, manually establishing an approximate center point of this shot group, and then re-aiming the gunner's sight reticle at the center point. Two different gunners fired the weapon at a 12 ft x 12 ft target. (It was found that a large target--12 ft x 12 ft or larger--was necessary to ensure hitting the target in the process of completing this procedure.) The target was placed 516 meters from the FCRS. The location of the target was chosen to accommodate range safety and topographical restrictions. The target was marked with a white aiming cross on a black background. The lines comprising the aiming cross were 2 inches wide and extended to the edge of the target on all four sides. Hits on the target were measured, in inches, vertically and horizontally from the center of the target aiming cross. Following this, one gunner fired additional shots in order to obtain an indication of the round-to-round dispersion of the system. All the alignment and zeroing correction values (the measured offsets when aligning and zeroing the system) were recorded and round-to-round dispersion data were collected.

Gunner Laying. The next test was a gunner laying test. This test was intended to obtain data to evaluate laying error and to define the nominal time for a gunner to manually lay the system on a target from various azimuth stand-off positions. Three trials were performed by each of two gunners who were required to slew the FCRS turret to bring the sight reticle onto a target aiming point. This was performed from six stand-off positions while the resulting data were recorded. The six stand-off positions were, in azimuth, ±0.2, ±0.4, and ±0.6 radians (±203.7, ±407.7, ±611.2 mil). An indication of gunner lay error can be obtained from a measure of the difference in the sight elevation and azimuth position angles from a predetermined reference position angle. The computer, using an internal clock, measured the time from the issuance of an event mark (when the command to lay on target was given) to trigger pull (which occurred at the moment the gunner determined he was on target).

Live Fire Against a Constant Velocity Moving Vehicle. The FCRS was tested against a constant velocity moving target to see if the system could be used effectively in a stationary to moving-target scenario. Two gunners fired from the stationary FCRS against a vehicle moving at about 10 mph at a range of about 510 meters. The drivers of the vehicle were instructed to maintain a speed of 10 mph for a course distance of about 200 meters. Hits were determined by a hit detector installed on the vehicle which gave an audible alarm whenever the target was hit. The target was shot at while moving from right to left and left to right.

Tracking Aids. A gunner tracking test was performed to evaluate the capability of the system to track a stationary target while on the move using the system's tracking aids function. The tracking aids function is provided to the system via computer software. A target was tracked from the FCRS as the FCRS was run on a course from right to left and left to right at a constant 5 mph on a road which was 670 meters from the target at the closest point. Two different program tapes, each with a different vehicle velocity scaling factor, were used for each of the runs.

RESULTS

Alignment, Zeroing, and Round-to-Round Dispersion. Alignment and zeroing correction values were obtained over a period of 8 days. Validation of the defined alignment and zeroing procedures was accomplished by the performance of these operations without encountering any procedural difficulties. Input alignment and zeroing correction values (see Table 1) properly altered the line of fire of the system to group the zero verification rounds in the area of the target aim point. (The onboard computer calculates correction values to 1/10,000 mil.) In each case, the system fired to the left and above the target aim point.

TABLE 1

Alignment and Zeroing Correction Values for Azimuth and Elevation (mil)

Date	Alignment Corrections Azimuth	Alignment Corrections Elevation	Zeroing Corrections Azimuth	Zeroing Corrections Elevation	Zeroing Accuracy[a] Azimuth	Zeroing Accuracy[a] Elevation
9-10-84	+5.325	-17.390	-2.800	-2.174	NA	NA
9-19-84	+5.825	-18.170	-3.650	-0.199	NA	NA
9-20-84	+4.275	-17.430	-1.949	-1.099	+0.02	-0.61
9-21-84	+6.300	-17.720	-2.099	-1.149	+0.05	-0.96
9-24-84	+4.975	-17.020	-2.350	-0.849	+0.27	+0.33
9-25-84	+4.150	-17.370	-2.274	-0.999	+0.07	+0.13
9-26-84	+4.950	-17.470	-3.125	-1.224	+0.35	-0.38
9-27-84	+4.400	-17.640	-1.974	-0.175	+0.20	+0.49

[a]Angular displacement from aim point of zeroing confirmation shot group center.

Note. A positive sign indicates a correction in the upward direction, and a negative sign indicates a correction in the downward direction.

NA means not available.

To get an estimate of the system's round-to-round dispersion, 51 rounds were fired. Four dispersion shot groups were fired, each after the M2 machine gun had been warmed and the system had been aligned and zeroed. Table 2 presents a summary of the dispersion data taken.

TABLE 2

Summary of Dispersion Data (mil)

Group	Date	N	Center of Impact x	Center of Impact y	Round-to-Round Dispersion x	Round-to-Round Dispersion y	Extreme Dispersion x	Extreme Dispersion y	Extreme Spread	Mean Dispersion x	Mean Dispersion y
1	9-20-84	20	-0.10	-0.47	0.33	0.07	0.91	1.30	1.31	0.16	0.18
2	9-27-84	10	0.33	0.07	0.26	0.60	0.94	1.85	1.85	0.20	0.49
3	9-27-84	10	0.25	0.90	0.29	0.75	0.94	2.04	2.06	0.22	0.68
4	9-27-84	11	0.13	0.11	0.29	0.48	0.86	1.82	1.85	0.24	0.31

Overall round-to-round dispersion: x - 0.29
y - 0.40

Notes.

Center of impact: x - Horizontal error (distance from the target aim point in the x-direction).

y - Vertical error (distance from the target aim point in the y-direction).

Round-to-round dispersion: Standard deviation of the distribution of the impacts about the aim point in the x-and y-directions.

Extreme dispersion: Difference between the greatest and smallest value in the shot group in the x-and y-directions.

Extreme spread: Greatest absolute distance between all possible pairs of shots on the target.

Mean dispersion: $\frac{1}{n} \sum_{i=1}^{n} \left| x - \bar{x} \right|$

Gunner Laying. Due to data collection software problems which existed at the time the gunner laying test was performed, data necessary to determine the azimuth lay errors were not obtained. These software problems resulted in incorrect scaling of the sight-traverse position data and in failure to properly update the turret-to-hull position data. Both of these software problems have subsequently been corrected, but due to time constraints, it was not possible to repeat the gunner laying test.

Live Fire Against a Constant Velocity Moving Vehicle. Five rounds were fired by each of two gunners against the Sheridan Scaled Tactical Target (S-ScaTT) (Figure 3) as it moved from left to right and five rounds by each as the S-ScaTT moved from right to left for a total of 20 rounds fired. On the first set of runs, the vehicle moved from right to left. One shot was fired per pass during five passes. Each shot hit the target. During the next set of runs, the target was run from left to right. Again, one shot was fired per pass during five passes. Each of these shots was also a hit. For the next set of five rounds fired at the target, which was moving from right to left, three shots were fired during the first pass and the remaining two rounds were fired during the second pass. Each of these shots hit the target. During the final set of five shots, which was fired against the target as it moved from left to right, all five rounds were fired on one pass. Each of these shots was also a hit. Each one of the 20 rounds fired at the moving target, therefore, hit the moving target.

Tracking Aids. The verification test of the tracking aids function indicated it was operational. This function allows a target to be tracked automatically by the vehicle based on the range to the target and the velocity of the FCRS. Both subjective evaluation by the operator and data recorded by the computer (i.e., turret traverse rates, sight angles, turret accelerations, and turret-to-hull angles) were used to assess the operation of the tracking aids function. A review of the data from these tests indicated, however, that the vehicle velocity signal scaling required correction.

A scaling change was computed from the data and implemented via a revision of the operational software. Unfortunately, due to range scheduling constraints, it was not possible to verify the new vehicle velocity signal scaling.

DISCUSSION

The purposes of the engineering tests conducted were to determine whether the Fire Control Research System was operational, and to ensure that all system defects encountered were corrected. The results from these tests indicated that:

- FCRS hardware contains no known serious system defects. Although turret backlash was discovered to be somewhat excessive, this can be lessened through adjustments to the turret traverse amplifier.

Figure 3. Sheridan Scaled Tactical Target (S-ScaTT).

- The tracking aids function is operable, and tracking rates can be modified via system software. However, further adjustments in the vehicle velocity signal scaling may have to be made to the software.

- The FCRS operational and data collection software is functional and contains no known problems which prevent utilization of the FCRS for its intended purpose.

CONCLUSION

These tests indicated that the FCRS currently has an operational capability sufficient to conduct a large variety of basic research even though the system does not contain certain features which would enable it to more fully simulate the fire control systems of real tanks, like a laser range finder and a fully operational commander's station. However, current plans call for the systematic incorporation of these features as budget constraints permit.

Although the system is operational, no detailed measures of FCRS performance accuracy exist. To isolate what changes in soldier-machine performance are attributable to the "man in the loop," it will be necessary to systematically test inherent FCRS armament delivery accuracy (including tracking performance) before much useful human factors testing can be performed.

RECOMMENDATIONS

The following recommendations are made:

1. Tests should be conducted to provide FCRS baseline data. These tests should also provide a basis for determining probabilities of hit under realistic field conditions and should allow a determination as to what changes in soldier-machine performance are attributable to the FCRS and to the human gunner.

2. To make the FCRS a more complete fire control research tool, the following additions should be made to the system:

   - Through-sight neodymium laser range finder.

   - Fully operational commander's station.

   - Tracking data gathering system (e.g., TV tracking system).

   - Fully autonomous van or trailer to house the support station computer system. This will enable the performance of in-the-field data reduction.

3. To prevent costly delays due to FCRS or S-ScaTT component failures, spares of key components should be obtained and reposited, namely system power supplies, amplifiers, computer components, and automotive parts.

REFERENCE

Delco Systems Operations. (1983, June). *FCRS vehicle: Customer orientation and training* (Section II: Operation and maintenance). Santa Barbara, CA: Author.

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